E01

Dynamic Strain Monitoring for Local Damage Detection in Steel Structures: Part I. Methodology

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1. Introduction

Recent earthquake events in Japan highlighted the difficulties in evaluating the integrity of large-scale buildings affected by strong ground motions. Making decisions about continued use of buildings in the wake of earthquakes needs quantitative information on damage in structural systems.

2. System Design

The requirement for a system that is effective and practical for post-earthquake assessment of building conditions includes: 1) capability of detecting the location and level of local damage in members; 2) efficiency in installation cost and labor; 3) durability for long-term usage.

Since the distribution of dynamic bending moments in a steel frame is solely determined by the stiffness relations between the members in the frame, the evaluation of changes in the distribution leads to the identification of members of which stiffness decrease by seismic damage. An array of strain sensors installed to steel members provides quantitative data for estimating the distribution of dynamic bending moment under small-amplitude dynamic excitations (e.g. ambient vibrations and minor earthquakes). Fig. 1 schematically illustrates the changes in the bending moment distribution of a steel frame based on a numerical simulation. With the reduction of stiffness in a beam by 50%, bending moments around the damaged beam is re-distributed and the new distribution is established. In this example simulation, the members only around the damaged part are affected with the reduction of bending moment by 5-18%. Since the moment distribution is weakly dependent on the characteristics of excitations, a comparative study of the distribution under ambient loading and micro earthquakes is possible.

3. Dynamic Strain Monitoring

A piezoelectric sensor called PVDF (PolyVinylidene DiFluoride) that produces voltage in proportion to compressive or tensile mechanical stress or strain (Fig. 2(a)), is adopted for measuring dynamic strain on steel beams. The notable advantage of the PVDF is high sensitivity with more than 10 mV output per microstrain, about 60 dB higher than the voltage output of a foil strain gage. Fig 2(b) compares responses of an accelerometer (top), a foil gage (middle), and a PVDF (bottom) in a vibration test of fix-supported beam under a white noise excitation. The PVDF and accelerometer successfully tracked the vibration behavior while a foil gage did not have enough sensitivity. The other notable advantages of the sensor include 1) reasonable price (1,200 JPY per sensor), 2) flexibility for handy deployment, 3) a broad-band operating frequency range (0.001 Hz to MHz), 4) no need for external power, and 5) long term durability with operating temperature of -40 to 60°C.

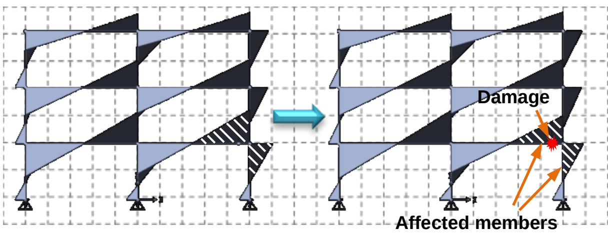
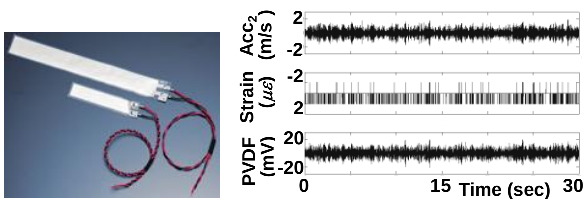


Fig. 1 Change in bending moment distribution with damage.



(a) (b)

Fig. 2 PVDF sensor: (a) PVDF sensor in film type; (b) responses to small amplitude excitation.